QUIPSS II with Thin-slice TI_1 Periodic Saturation (Q2TIPS): A Method for Improving Accuracy of Quantitative Perfusion Imaging

W.-M. Luh, E. C. Wong*, P. A. Bandettini, and J. S. Hyde
Biophysics Research Institute, Medical College of Wisconsin, Milwaukee, WI USA
*Department of Radiology and Psychiatry, University of California, San Diego, CA USA

Introduction: QUIPSS II was introduced by Wong *et al.* (1) to improve quantification of perfusion using pulsed arterial spin labeling (ASL) techniques. A well-defined bolus of tagged blood is created and delivered to the imaging slices by applying a saturation pulse (90° pulse + crusher gradient) in the tagging region at TI_1 before the images are acquired at a later time TI_2 (Fig. 1a-b-c). Under these circumstances the perfusion signal is directly proportional to TI_1. In the previous implementation (2), residual errors occurred because of the imperfect match of the slice profile of the TI_1 saturation pulse to that of the inversion pulse at the distal edge (the edge further away from the heart), and the imperfect saturation of the TI_1 pulse. The present abstract describes and tests a method to minimize these errors. We refer to it as QUIPSS II with Thin-slice TI_1 Periodic Saturation (Q2TIPS).

Methods: In Q2TIPS, the single saturation pulse at TI_1 of QUIPSS II is replaced by a series of smaller saturation pulses applied at the distal end of the tagging region. The distal edge of the saturation pulses match that of the inversion pulse. Fig. 1a-d-e-f-c illustrates the timing and notation of this method where TI_{1S} is the stop time of the TI_1 saturation pulses. The TI_1 saturation slice is 2 cm and the TI_1 saturation pulse is a 3.2 ms sinc pulse applied every 50 ms and followed by a crusher gradient. All images were acquired using a 3T Bruker Biospec 30/60 scanner. A three-axis local head gradient coil and an endcapped quadrature birdcage coil were used. Single-shot blipped gradient echo EPI acquisition was used with 24 cm FOV and 8 mm slice thickness. The PICORE tagging scheme was used with a 10 cm tag created by a hyperbolic secant pulse with a 1 cm gap relative to the imaging slice. TI_2 was 1.4 sec while TI_1 varied from 0.2-1.2 sec. TE was 27.2 ms and TR was 2.5 sec. Typically 100 repetitions were acquired and averaged after pairwise subtraction to generate a perfusion map. Perfusion quantification was performed using a kinetic model (3) with an assumed T_1 of blood of 1.5 sec.

Results: The thickness of the TI_1 saturation slice and the application rate of the TI_1 RF pulses determine the maximum flow velocity of the tagged blood to be saturated. The signal of the tagged blood with an average velocity less than 40 cm/sec traveling through the saturation slice will be destroyed. Since the tagged blood slows down as it approaches the capillary bed and the saturation slice is close to the imaging slice, current implementation should be sufficient to null the signal of remaining tagged blood which is destined for the imaging slices. When the velocity is higher than 40 cm/sec, it is more likely that blood will have passed the imaging slices. The minimum number of TI_1 saturation pulses is determined by the time when the end of the tagged blood reaches the saturation slice. Although the TI_1 saturation pulses can be applied continuously until just before the imaging acquisition, excessive TI_1 saturation pulses will decrease the refreshing rate of the blood in the tagging region, which in turn increases the minimum TR. The anatomical image and the perfusion maps of QUIPSS II and Q2TIPS at TI_1 of 0.8 sec are shown in Fig. 2. The overall signal is lower in Q2TIPS and the bright signals in large veins also decrease. The averaged signals of QUIPSS II and Q2TIPS over gray matter ROIs are shown in Fig. 3a as a function of TI_1 and the calculated perfusion is shown in Fig. 3b with TI_{1S} for Q2TIPS at 1.25 sec. The accuracy of perfusion measurement with Q2TIPS is dramatically improved as is evident from the linear regression curve with near-zero intercept in Fig. 3a. The calculated perfusion is overestimated in QUIPSS II mainly due to the imperfection of the TI_1 saturation pulse, especially at short TI_1. The averaged perfusion from the six data points obtained with Q2TIPS is 65±3 ml/100 ml/min. Fig. 3c shows the Q2TIPS signal as a function of TI_{1S} from 0.75 sec to 1.25 sec with TI_1 at 0.7 sec. For TI_{1S} too short, tagged blood at the tail of the tag reaches the imaging slice, and the inflection in this curve indicates the time at which the tail of the tag reaches the proximal end of the saturation band. Fig. 3d shows the Q2TIPS signal with TI_1/TI_{1S} at 0.7/1.1 sec as a function of TR. The signal decrease with TR shorter than 2.1 sec is due to the incomplete refreshing of blood in the tagging region. Since the TI_1 saturation slice is close to the imaging slice, the tagged blood destined for the imaging slice travels relatively slowly through the saturation slice and takes longer to replenish.

Conclusions: Q2TIPS improves the accuracy of quantitative perfusion measurement with pulsed ASL by providing a cleaner cut-off of the tag at TI_1 at the expense of slightly longer minimum TR.

References:

1. Wong, E. C., *et al.*, *ISMRM Proceedings*, 85, 1997.
2. Wong, E. C., *et al.*, *ISMRM Proceedings*, 1761, 1997.
3. Wong, E. C., *et al.*, *NMR Biomed.* (in press).

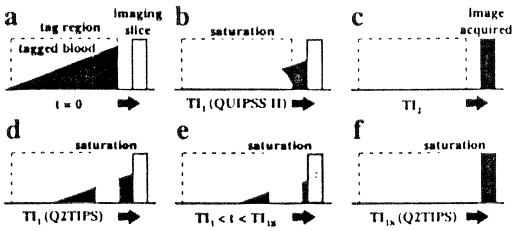

Figure 1. Timing diagram of QUIPSS II (a-b-c) and Q2TIPS (a-d-e-f-c) as the tagged blood approaches the imaging slice. The diagram for the tagged blood represents only blood destined to go to the imaging slice.

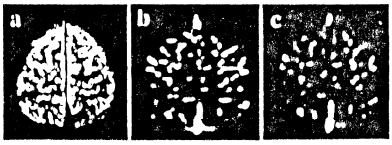

Figure 2. (a) Anatomical and perfusion images of (b) QUIPSS II and (c) Q2TIPS with TI_1 at 0.8 sec.

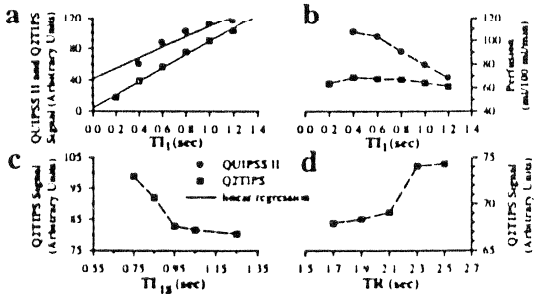

Figure 3. (a) QUIPSS II and Q2TIPS signals and (b) calculated perfusion *vs.* TI_1. Q2TIPS signal *vs.* (c) TI_{1S} and (d) TR.

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Please type the name and complete mailing address of the first author

Name: Wen-Ming Luh
Address: Biophysics Res. Inst., Medical College of WI, 8701 Watertown Plank Rd., Milwaukee, WI 53226
Country: U.S.A.
Telephone: (414) 456-4592
FAX: (414) 456-6512